

Characterization of Midface Fractures Incurred in Recent Wars

Christopher P. Kittle, DDS,* Adam J. Verrett, DDS,† Jesse Wu, BS,* Davin E. Mellus, DMD,‡
Robert G. Hale, DDS,‡ and Rodney K. Chan, MD‡

Background: Facial injuries sustained by US military personnel during the wars in Iraq and Afghanistan have increased compared with past conflicts. Characterization of midface fractures (orbits, maxilla, zygoma, and nasal bones) sustained on the battlefield is needed to improve our understanding of these injuries, to optimize treatment, and to potentially direct strategic development of protective equipment in the future.

Methods: The military's Joint Theater Trauma Registry was queried for midface fractures from 2001 to 2011 using *International Classification of Diseases, Ninth Revision* diagnosis codes. Stratification was then performed, and individual treatment records from Brooke Army Medical Center were reviewed. Analysis of the fracture pattern, treatment, and complications was performed.

Results: One thousand seven hundred sixty individuals with midface fractures were identified. Those fractures sustained in battle were characterized by a predominance of open fractures, blast etiology, and associated injuries. Detailed record reviews of the patients treated at our institution revealed 45% of all midface fractures as operative. Thirty one percent of these were treated at levels III and IV facilities outside the continental United States before arrival at our institution. Patients with midface fractures underwent multiple operations. There was a 30% rate of complication among operative fractures characterized by malalignment, implant exposure, and infection. Midface battle injuries also had a high incidence of orbital fractures and severe globe injuries.

Conclusions: Midface fractures sustained in the battlefield have a high complication rate, likely as a result of the blast mechanism of

injury with associated open fractures, multiple fractures, and associated injuries. These cases present unique challenges, often requiring both soft tissue and skeletal reconstruction.

Key Words: Maxillofacial, facial fractures, early rigid fixation, blast injury

(*J Craniofac Surg* 2012;23: 1587–1591)

The percentage of facial injuries sustained in these 2 conflicts has increased from past US military conflicts, possibly related to advances in body armor and faster medical evacuations. The end result is that previously lethal insults are now becoming increasingly survivable.¹ In a recent review of injuries sustained throughout the past 10 years, the percentage of battle injured patients evacuated out of theater with craniomaxillofacial (CMF) injuries is 43%.^{2–7} These injuries included all soft and hard tissue insults to the face, with the exception of isolated intracranial injuries, tympanic membrane ruptures, and corneal abrasions. Craniomaxillofacial fractures (consisting of fractures of the mandible, maxilla, zygoma, nasal bones, and orbits) were found in 13.2% of battle injured US service members requiring evacuation out of theater. The great majority of these fractures were sustained on the battlefield by high energy explosives.^{7,8}

Several other studies in the literature have performed reviews of CMF fractures sustained in the wars in Iraq and Afghanistan. Breeze et al⁹ studied 448 British soldiers over the 5 year period from 2003 to 2008. There were 164 CMF fractures documented among the nearly 450 soldiers in their study population. A review of the Navy Marine Corp Combat Trauma Registry by Wade et al¹⁰ reported 802 CMF fractures sustained by 1011 Marines in Iraq during a major combat phase (March 2004 to September 2004). Both studies extracted data from a relatively limited period, which can either underrepresent or overrepresent the incidence of maxillofacial fractures. Although CMF fractures were not directly correlated with the method of injury in either study, both studies implicated explosive devices as the primary cause of injury (64% and 75%, respectively), with ballistics coming in a distant second at 14% and 7%, respectively.^{9,10} This same etiology of injury is consistent with the primary reported mechanism of injury sustained by US troops as found by Owens et al.⁸

As a comparison, Levin et al investigated the CMF injuries sustained during the Second Lebanon War, which occurred in the summer of 2006. He found that 36 of 565 total wounded (6.4%) had facial injuries. Among these, there were 33 CMF fractures, a relatively small percentage in comparison to the conflicts in Iraq and Afghanistan. Although the mode of injury was once again dominated by explosives (77%), the reduced rate of facial injuries as compared with other conflicts might be explained by the type of warfare being waged. The Second Lebanon War was characterized mainly by use of infantry personnel, who often sustained body and extremity wounds as a result of increased exposure to devices



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From the *Brooke Army Medical Center, Fort Sam Houston; †Wilford Hall Medical Center, Lackland Air Force Base; and ‡US Army Institute of Surgical Research, Fort Sam Houston, Texas.

Received October 19, 2011.

Accepted for publication March 12, 2012.

Address correspondence and reprint requests to Rodney K. Chan, MD, Dental and Trauma Research Detachment, US Army Institute of Surgical Research, 3650 Chambers Pass, Fort Sam Houston, TX 78234; E-mail: rodney.k.chan@us.army.mil

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The authors report no conflicts of interest.

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ISSN: 1049-2275

DOI: 10.1097/SCS.0b013e318256514a

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 01 NOV 2012		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Characterization of midface fractures incurred in recent wars				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Kittle C. P., Verrett A. J., Wu J., Mellus D. E., Hale R. G., Chan R. K.,				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) United States Army Institute of Surgical Research, JBSA Fort Sam Houston, TX				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT UU	18. NUMBER OF PAGES 5	19a. NAME OF RESPONSIBLE PERSON
a REPORT unclassified	b ABSTRACT unclassified	c THIS PAGE unclassified			

TABLE 1. ICD-9 Diagnosis Codes

ICD-9 Diagnosis Code	Description
802	Nasal bone Fx closed
802.1	Nasal bone Fx open
802.4	Fx malar/maxillary closed
802.5	Fx malar/maxillary open
802.6	Fx orbital floor closed
802.7	Fx orbital floor open
802.8	Fx other facial bone closed
802.9	Fx other facial bone open

such as landmines.¹¹ In contrast, the recent conflicts in Iraq and Afghanistan saw more injuries from within armored vehicles where there is relative protection for the body and extremities but the head and face still exposed to blast overpressure, concussive force, and shrapnel.

Similar to one of the cohorts of this analysis, most studies of the modern battlefield divide injuries using *International Classification of Diseases, Ninth Revision (ICD 9)* diagnosis codes to categorize injuries to anatomic regions such as head, face, and neck. The data contained in these studies are often broad and nonspecific. Although these studies have provided valuable data, no study has yet concentrated exclusively on the treatment and outcomes of mid face fractures. It is the goal of this study to investigate those soldiers who sustained midface fractures (to include the maxilla, zygoma, nasal bones, and orbits) during the wars in Iraq and Afghanistan, both as a broad group and in detail for those who were treated at Brooke Army Medical Center (BAMC). This information will improve understanding, optimize treatment, and potentially direct strategic development of protective equipment in the future.

MATERIALS AND METHODS

This study has been conducted under a protocol reviewed and approved by the US Army Medical Research and Materiel Command Institutional Review. A retrospective review was performed utilizing the Joint Theater Trauma Registry (JTTR). This large database is a compilation of all US service members injured in Operations Iraqi Freedom (OEF) and Enduring Freedom (OIF) admitted to a level III or higher military treatment facility. It spans all military services and includes data beginning with the OEF conflict in October 2001, expands to include OIF data, and continues to document pertinent data through the present day. It uses the Abbreviated Injury Score, the *ICD 9, Clinical Modification*, diagnosis and procedure codes, and information abstracted from the patients' medical record. It also uses expert clinical inference and process improvement data.

Patient demographics including age, sex, branch of service, injury type, Injury Severity Score (ISS), and mechanism of injury were tabulated and stratified. The fracture pattern was identified based on analysis of *ICD 9* diagnosis codes (Table 1). Patients known to be treated at BAMC (Fort Sam Houston, TX) were further identified, and their electronic medical records reviewed including available progress notes, operative notes, radiographs, and radiology reports.

The study database was maintained under data encryption in Access (Microsoft, Redmond, WA). Basic univariate analyses were used to analyze the resulting data sets. Where not indicated, significance is set at $P < 0.05$.

RESULTS

The Department of Defense reported that a total of 43,822 servicemen and servicewomen were injured during the 10 year pe-

riod from 2001 to 2011.⁷ Among them, 23,609 had injuries that required evacuation to a level III Combat Support Hospital (CSH), 13,037 to a level IV regional medical center (Landstuhl Regional Medical Center [LRMC], Germany), and 11,052 to a level V state side medical facility. Based on a search of the *ICD 9* diagnosis codes, 12,028 patients were identified as having CMF injuries (to include fractures, dislocations, soft tissue injuries, nerve injuries, vessel injuries, burns, tympanic membrane ruptures, tooth injuries, corneal abrasions, and intracranial injuries), and 2763 patients were identified as having some type of fracture to the facial skeleton. After exclusion of skull, vault, basilar, tooth, and mandible fractures, 1760 subjects were found to have midface fractures (defined as fractures of the orbit, maxilla, zygoma, and nasal bones). These 1760 soldiers make up 13.5% of patients who required transfer out of theater (denominator, 13,037).

The demographics of those patients with midface fractures as indicated by the JTTR are listed in Table 2, stratified based on injury type (battle and nonbattle). Battle injured patients made up 72% of those with maxillofacial fractures, whereas non battle injured patients made up the remaining 28%. The ISS of battle injured patients was the only variable found to be statistically significant in the demographics table ($P < 0.10$). No significant statistical difference in the age, OEF/OIF status, or distribution of the injuries among the various military branches was found. By comparing known BAMC hospital medical record numbers against the JTTR cohort, a subcohort of 201 patients with purported midface fractures was identified. After a thorough review of the medical records, however, only 83 individuals of the subject population had clear documentation of maxillofacial fractures (Table 3).

The demographics of the BAMC cohort were comparable to the parent JTTR population, with no significant statistical differences. The average age of JTTR subjects was 26.5 years, whereas the BAMC group was only slightly older at 27.5 years. The ratio of males to females was similar. The JTTR group was 98% males to 2% females, whereas the BAMC group was 96% males and 4% females. Similarly, 74% of the JTTR and 73% of the BAMC group were injured in Iraq, whereas the remaining 26% and 27%, respectively, were injured while serving in Afghanistan. A greater percentage of Army personnel and a slightly smaller percentage of Marine personnel were treated at BAMC, an expected finding for an Army facility. The BAMC cohort also had a higher proportion of battle injured soldiers at 87.9%. These patients had a greater acuity and a higher ISS as compared with similarly battled injured patients (24.01 vs 18.25) in the JTTR cohort. Battle injured patients treated at BAMC were also found to have a higher ISS (18.8 vs 9.8).

TABLE 2. JTTR Demographic Data

	Total	Battle Injuries	Nonbattle Injuries
Total patients	1760	1259 (71.53%)	497 (28.24%)
Average age, y	26.46	26.07	26.4
Sex			
Male	1729 (98.24%)	1241 (98.57%)	481 (96.78%)
Female	35 (1.99%)	18 (1.43%)	16 (3.22%)
Military operation			
OIF	1309 (74.38%)	915 (72.68%)	389 (78.27%)
OEF	455 (25.85%)	344 (27.32%)	108 (21.73%)
Branch			
Air Force	46 (2.61%)	25 (1.99%)	21 (4.23%)
Army	1320 (75%)	948 (75.30%)	364 (73.24%)
Navy	54 (3.07%)	30 (2.38%)	24 (4.83%)
Marines	344 (19.55%)	256 (20.33%)	88 (17.71%)
Survival	1703 (96.76%)	1206 (95.79%)	489 (98.39%)
ISSs		18.25	9.8

TABLE 3. BAMC Demographic Data

	Total	Battle Injuries	Nonbattle Injuries
Total patients	83	73 (87.95%)	10 (12.05%)
Average age, y	27.45	27.59	26.4
Sex			
Male	80 (96.39%)	70 (95.89%)	10 (100%)
Female	3 (3.61%)	3 (4.11%)	0 (0%)
Military operation			
OIF	61 (73.49%)	53 (72.60%)	8 (80%)
OEF	22 (26.51%)	20 (27.40%)	2 (20%)
Branch			
Air Force	3 (3.61%)	3 (4.11%)	0 (0%)
Army	73 (87.95%)	63 (86.30%)	10 (100%)
Navy	2 (2.41%)	2 (2.74%)	0 (0%)
Marines	5 (6.02%)	5 (6.85%)	0 (0%)
Survival	82 (98.80%)	72 (98.63%)	10 (100%)
ISSs		24.01	18.8

The predominant mechanism of injury among the battle and non battle injured JTTR population was explosives at 62.1%. Explosives were also the principal cause of midface fractures among the combined BAMC cohort at 84.3%.

Further stratifying the 2 groups into only those injuries sustained in battle resulted in an expected increase in the role of explosives, with the JTTR cohort at 85% and the BAMC cohort at 94%. Ballistics came in a distant second in both groups, with the JTTR showing 11% and the BAMC group at 3%. The remaining battle injuries came from diverse causes such as motor vehicle accidents, plane and helicopter crashes, and blunt trauma of unknown mechanism (Fig. 1).

Examination of fracture patterns among the JTTR population revealed 1472 subjects with ICD 9 diagnosis of midface fractures and a total of 2916 individual midface fractures (an average of 1.7 fractures per patient). The number of fractures sustained per patient is represented in Figure 2. The distribution of fractures of the JTTR group is as follows: orbit (17%), nasal (26%), maxillary (28%), and arch/other (29%). Little change was observed in the distribution of fractures when only battle injuries were considered (Table 4). Conversely, the BAMC cohort was weighted more heavily toward orbital fractures. The 83 BAMC subjects had 168 fractures, with an average of 2.02 fractures per patient. The distribution of fractures was as follows: arch/other, 11%; nasal, 15%; maxilla, 29%; and orbit, 45%. The BAMC group also showed little change in the distribution of fractures when only battle injuries were selected.

Based on the ICD 9 codes, 46.0% of all midface fractures sustained by the JTTR population were classified as open. This jumped to 54.8% when only the battle injured group was considered. Unfortunately, characterization of the BAMC wounds as open or

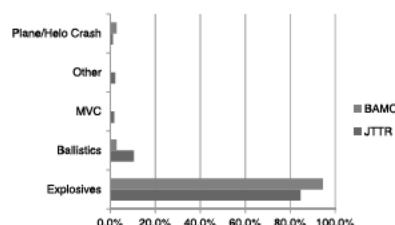


FIGURE 1. Mechanism of injury among battle-injured patients with midface fractures. For both the JTTR and BAMC cohorts, explosives account for the vast majority of the mechanism for injury. This is followed by a distant second by ballistics and then motor vehicle collision.

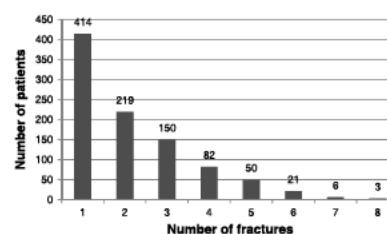


FIGURE 2. Number of midfacial fractures sustained per battle-injured soldier, evacuated out of theater. The number of fractures is tabulated based on the ICD-9 codes listed in Table 1. A patient with a code for an open fracture and a code for a closed fracture of the same type but in separate areas is counted as having 2 separate fractures. An average of 1.7 fractures was sustained per injured service member in the JTTR cohort and 2.0 fractures per patient in the BAMC cohort.

closed was not possible. Insufficient data in too many of the digital medical records made it impossible to determine whether the wounds sustained were open or closed.

It was found that 55% of injured personnel (to include in injuries of any kind) who made it to a level III facility were subsequently evacuated to level IV and that, ultimately, 47% of injured soldiers who made it to level III were evacuated to level V. In contrast, those soldiers who sustained midface fractures and were evacuated to a level III facility demonstrated a propensity for needing evacuation to higher levels of care, with 90% being evacuated to a level IV and 75% ending up at a level V facility. Among midface fractures, fractures of the maxilla and zygoma were the most common fracture types that were transferred (Fig. 3).

The BAMC cohort varied in where definitive fracture treatment was performed. Operative fractures not fixed at BAMC were fixed either at a level III or level IV facility (CSH/LRMC). Our analysis does not make a distinction between these two. Levels III and IV facilities accounted for 31% of operative fixations of the BAMC population.

An analysis performed to compare treatment rendered at CSH/LRMC versus BAMC noted earlier treatment and fewer complications in the CSH/LRMC group. Patients treated at CSH/LRMC required fewer total and face related operations but a similar number of skeletal operations (Table 5). The 2 subgroups clearly differ in the timing of the operation, with the earliest operation performed at BAMC at 5 days. The average treatment interval for the BAMC cohort was 12 days, whereas that for CSH/LRMC was 2.36 days.

The soldiers treated at BAMC often had polytraumas, with only a portion of their injuries coming from their midface fractures. Hospital data revealed the average number of operations per patient, to include treatment of all bodily injuries, to be 7.1. The total number of operations varied but ranged anywhere from 0 to 35 procedures. Of these, 4.7 operations (range, 0–28 operations) were localized to the face, with 1.8 operations (range, 0–4 operations) specific for fracture treatment (open reduction internal fixation [ORIF], bone graft, free osseous transfer). Patients with nonoperative fractures also demonstrated a similar number of total operations. When broken down by region, ORIF was performed on 4%

TABLE 4. Fracture Distribution

Fracture Location	JTTR Population	JTTR Battle-Injured Group	BAMC Population	BAMC Battle-Injured Group
Maxilla	28.0%	28.0%	29.0%	30.0%
Nasal	26.0%	24.0%	15.0%	16.0%
Orbit	17.0%	18.0%	45.0%	42.0%
Zygoma	29.0%	29.0%	11.0%	12.0%

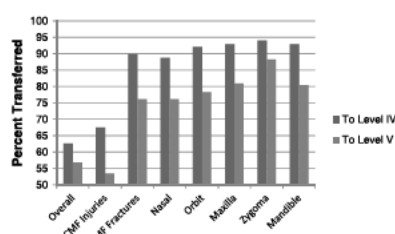


FIGURE 3. Escalation of care among midface-fracture, battle-injured patients. The percentage of total injured patients who required evacuation to higher levels of care was compared with patients with CMF injuries and various types of maxillofacial fractures; 55% and 47% of injured soldiers were evacuated to levels IV and V facilities, respectively. In comparison, soldiers with midface fractures demonstrated a propensity for needing evacuation to higher levels of care, with 90% being evacuated to a level IV and 75% ending up at a level V facility. Among midface fractures, fractures of the maxilla and zygoma were the most common fracture types that were transferred.

of the nasal fractures, 21% of maxilla fractures, 43% of orbital fractures, and 53% of arch fractures.

Among 36 patients who required operative interventions, all but one was battle injured. Complications were defined by the need for unanticipated skeletal interventions and were noted in 31% of patients and 36% of battle injured patients (Table 6). The most common complication was improper reduction of fracture fragments leading to malocclusion or entrapment of orbital contents. Other complications included implant exposures, infected bone grafts, and dural leaks. An analysis to determine the risk factors for complications was performed. Age and ISS did not demonstrate any statistical differences between the 2 groups, whereas facial ISS demonstrated some significance ($P \leq 0.10$).

Early fracture reduction rendered at Echelon III and IV facilities was found to be associated with a decreased risk for complications. Lower facial ISS was also found to be associated with fewer complications.

DISCUSSION

Demographic analysis of both the JTTR and BAMC cohorts revealed that age, sex, and the theater of operations in which the subjects were injured were nearly identical. The mechanism of injury of the 2 groups was also similar. The majority of battle injured subjects were the victims of blast. Unfortunately, no definitive data exist in either study as to exactly which type of explosive device was responsible on a case by case basis. Ballistics injuries were a distant second in both studies. For nonbattle injuries to the midface, motor vehicle accidents were the most common followed by blunt injuries of unknown etiology.

TABLE 5. Analysis of BAMC Cohort With Operative Midface Fractures

	Total	Operated on Before BAMC Arrival	Operated on at BAMC
Subjects with operative fractures	36	11	25
Average no. days between injury and operative management	9.5	2.3	12.6
Range of days from injury and operative management	1-44	1-8	5-44
ISS	21.63	26.36	19.56
Facial ISS	2.22	2.18	2.24
Total operations	7.06	6.36	7.36
Total operations involving the face	4.72	3.27	5.36
Total operations involving midface Fractures	1.81	1.73	1.84

TABLE 6. Analysis of BAMC Cohort Requiring Operative Intervention

	Complications	No Complications
BAMC patients who required operative intervention (n = 36)	11	25
Average age, y	31.9	25.2
Total operations	8.6	6.0
Average no. operations on the face	6.5	3.6
Average no. operations on midface fractures	2.8	1.4
No. days from injury to surgical intervention of CMF fractures	12.5	8.3
ISS	21.8	21.0
Facial ISS	2.2	1.7
Percentage of the BAMC cohort (n = 83)	13	30
Percentage of those who received surgical intervention (n = 36)	31	69
Treated at BAMC (n = 25), %	36	64
Treated at a level III or IV facility (n = 11), %	18	82

Operations Iraqi Freedom and Enduring Freedom used a system of evacuation to transport wounded soldiers to higher echelons of care based on patient requirements. Analysis within the context of this evacuation system demonstrated that 90% of those subjects with midface fractures were evacuated to level IV facilities and that 75% were evacuated to level V facilities. These extremely high percentages of evacuation cannot be wholly attributed to isolated midface fractures, especially in light of the many concomitant injuries that these soldiers have often sustained. However, these numbers still provide a general understanding that these injuries often require treatment at the highest echelons of care.

The midface fractures sustained by US military forces were characterized by both multiple and open fractures.⁶ Early treatment of these fractures was associated with fewer complications, which may support the philosophy of Manson et al,^{12,13} who strongly advocated early rigid fixation to achieve reduced swelling and better skeletal alignment. In addition, elevated overall ISSs (indicating multiple wounds not related to the head or neck) did not preclude fracture fixation. Indeed, many of the study subjects with elevated ISSs were shown to have been repaired at levels III and IV despite their concomitant wounds. This early fixation was associated with the same number of skeletal operations but fewer total facial operations performed, which may suggest that early intervention by an expert before accumulation of gross amounts of edema might lead to fewer complications. Another plausible and more likely explanation is that the most extensive injuries were not treated until arrival at BAMC, which may account for the increased number of complications seen with this cohort. This is corroborated by an elevated facial ISS found in those patients who have complications.

A 30% complication rate was found among operative fractures performed at BAMC. The most common complications observed were malalignment, implant exposure, and infection. Soft tissue revisions were not included because of the impossibility of distinguishing a complication secondary to the operation itself as opposed to one resulting from the initial trauma.

Subjects with battle injured midface fracture required a large amount of operative resources for treatment of their wounds. The number of operations required to fix the facial skeleton paled in comparison to the operations needed for the facial soft tissue. One of the soldiers in the BAMC cohort with nonoperative facial fractures required a total of 35 operations, 28 of which were operations on the face (Table 5). Concomitant facial burns, as an example, significantly increase the number of operations needed for soft tissue coverage. In fact, patients with nonoperative fractures required a

similar number of total operations, highlighting the complexity of the soft tissue injuries.

Open reduction internal fixation in our population was performed in 21% of maxilla fractures, 43% of orbital fractures, and 53% of arch fractures. Comparable civilian series demonstrates a rate of 46.3% for ORIF of zygoma fractures.¹⁴ Although it is not always applicable to compare 2 data sets that might have slightly different definitions of various fractures, we did note that our rate of ORIF for maxilla fractures was quite low. This might be secondary to a heterogeneous population of fractures all lumped into this category including isolated anterior wall fractures and complex Le Fort type fractures. Also, associated injuries to other body systems might have resulted in a lower rate of ORIF. The rates of fixation for orbital and arch fractures are similar to expected civilian rates.

Although there were many similarities between the JTTR and BAMC groups in this study, one unique finding among the BAMC group is the higher proportion of orbital fractures and fractures of the maxilla (Table 4). No statistically significant changes were encountered by selecting for only battle injured soldiers.

Several reasons for the observed differences in fracture patterns may be postulated. First, multitrauma, by its nature, is chaotic, and in depth secondary surveys and definitive radiographic examinations may not be feasible to perform at lower echelons of care. An injured soldier is typically stabilized and then evacuated to the most appropriate level of care as soon as possible. It is often only when the subject arrives at a level V facility that comprehensive examinations by specialists are performed. A good example of this phenomenon was encountered in the compilation of information for this research. Data from JTTR indicated that 201 soldiers with midface fractures were treated at BAMC. However, a thorough record review of these 201 subjects revealed only 83 of the 201 actually had evidence of midface fractures. A small number were found to have documented fractures limited to the mandible or dentition, but many had no mention of midface fractures in their medical records despite being identified as having such by the JTTR.

Furthermore, maxillofacial fractures are not commonly encountered by general medical providers. Although gross fractures might be readily apparent to a nonspecialist who views a computed tomographic scan, subtle fractures such as minimally displaced nasal fractures and nondisplaced orbital fractures often go unrecognized and undocumented. It is often only when the patient reaches a high level of specialty care and is thoroughly evaluated by a facial trauma expert that some of these findings are made. Conversely, it is not uncommon to find fractures that are incorrectly diagnosed and documented.

While analyzing the data for this study, we noted that almost 20% of those soldiers with orbital fractures among the BAMC cohort were found to have had an enucleation of at least 1 eye. Clearly, battlefield explosives pose a significant risk of vision loss and further emphasize the high energy kinetics imparted by the blast. Although it would be interesting to know how many subjects in our group were wearing ballistic goggles or glasses at the time of injury, this information is also not readily available.

High energy explosives have resulted in an increasingly high incidence of CMF injuries with associated midface fractures. Operative repair is characterized by need for both soft tissue repair and skeletal fixation. This study has identified a subset of patients with severe skeletal trauma that can benefit from further study, including their long term outcome and disability.

ACKNOWLEDGMENTS

The authors thank Mr. James San Antonio, SAMMC Department of Orthopaedics, and Mr. James Aden for their invaluable assistance on this project as well as the JTTR for providing data for this study.

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